On the Detection of Absolute Motion Relative to a Preferred Frame

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From the classical perspective, it is well known that the use of the Lorentz-Fitzgerald contraction of bodies in the direction of motion explains the null results reported by Michelson & Morley in their famous experiment (and all successive repetitions). In this paper, using a one-way interferometer and taking into account Lorentz-Fitzgerald contraction, we show that it is possible to detect changes in the interference pattern proportional to the velocity of the interferometer relative to a preferred frame in which light's speed is 'c'.

Introduction

Before Young's experiments in the 19th century, when he made interfere two light wave fronts, many experiments had already been done with the purpose of determining various properties of matter and light itself.

Given that many experiments demonstrated the wave-like nature of light, and therefore the belief that light propagated through a physical medium, during the 19th and 20th century many different experiments were made to find this medium, so called "*luminiferous aether*".

The postulation of Maxwell Equations of Electromagnetism (1865) encouraged further the search of the *'ether'*, because it was needed to find the medium over which light propagated with speed 'c', predicted in the derived electromagnetic wave equation.

As it is today generally accepted, such 'ether' has never been found. All experiments have been reported null or results obtained have been *much less than expected* (as for example the very famous Michelson and Morley Experiment in 1887). Among many, experiments claim to have reduced the existence of the 'ether' with wonderful precision [1].

Before the Special Theory of Relativity (STR) was postulated by Einstein in 1905, the scientific community had theories that explained the null results obtained in the experiments in search for the

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‘ether’. Michelson & Morley’s (M&M) results were explained by Lorentz, introducing his well known transformations, predicting a contraction of bodies in the direction of their motion (or, equivalently, perpendicular expansion). This is known as Lorentz-Fitzgerald contraction.

In 1905, Einstein postulated the Special Theory of Relativity (STR), which had great success among the community of physicists, and that also explained the results of the M&M experiment, as well as all previous null experiments. Although analogous formulations of the Lorentz-Fitzgerald contraction can be obtained as a result of Einstein’s postulates, the interpretation of the results differs greatly.

In Einstein’s perspective, the ‘ether’ doesn’t exist, there is no relative motion between light and observer. The observer always measures the speed of light as the universal constant ‘c’. In classical physicist’s perspective, the ‘ether’ *does* exist as the medium over which light propagates. Hence, for an observer moving relative to the ‘ether’, the speed of light relative to the observer is different from ‘c’.

On the next formulations, the Contraction of Bodies in the direction of motion is considered as *ad-hoc* principle. It is shown that changes in the interference pattern can be obtained when an interferometer as the one proposed is rotated.

Theory

It will be shown that changes in the interference pattern can be measured when a one-way interferometer is rotated. Classical pre-relativistic concepts such as the Lorentz-Fitzgerald contraction of bodies in the direction of movement are used. Velocities are considered relative to a preferred inertial referential frame where the speed of light is the same in all directions and has a constant value of ‘c’.

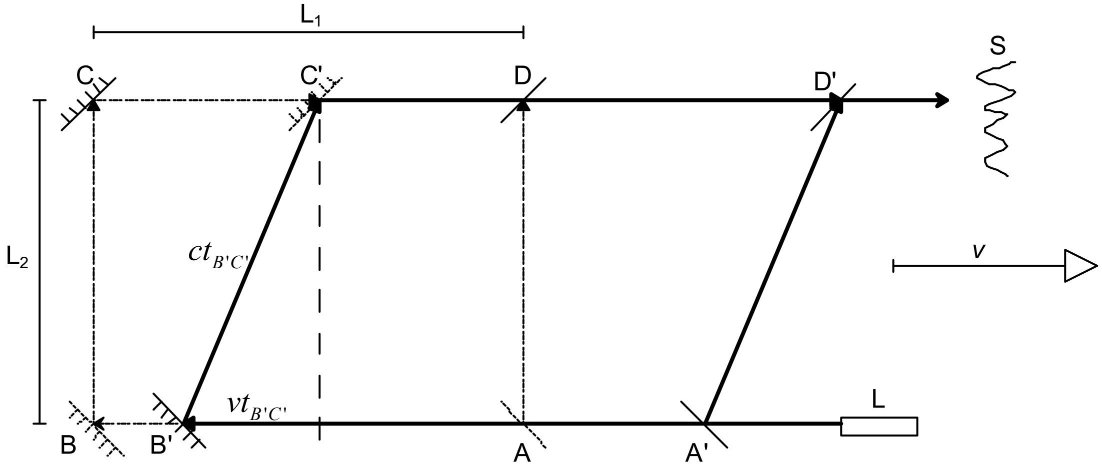

Figure 1 Interferometer by which calculations are made. Thin dotted lines represent the path light travels when the interferometer at rest (v=0), thick solid lines represent the path light travels when the interferometer moves with v>0, the dashed line help visualize a right triangle of sides $vt_{B'C'}$ and L_2 and hypotenuse c $t_{B'C'}$.

Consider an interferometer as the one shown schematically on Figure 1. When analyzed at rest, light emitted by the source located at L reaches beam splitter located at A. One beam travels the optical path between points $ABCD$, while the other travels AD. Both beams recombine at D, and the interference pattern can be seen on the screen S.

When the interferometer travels at a speed v with respect to the preferred frame, while the beam of light travels from A to B, the mirror at B moves to position B'. In this fashion, one beam travels the distances between points $AB'C'D'$. For both beams to recombine at D' at the same time and interference can be seen, the second beam must be travel the path $A'D'$.

Without loss of generality, for all purposes it can be considered the screen S as located at D'.

In order to obtain the time taken by each beam to reach D', we have to consider Lorentz-Fitzgerald contraction of bodies in the direction of their motion. We express this factor with the parameter $\alpha = \sqrt{1-\frac{v^2}{c^2}} < 1$, where c is the speed of light, and v is the speed of the interferometer, both relative to the preferred frame.

As we will analyze the interferometer in two different orientations, for all subsequent formulations, the superscript $i=1,2$ denotes the first and second orientation, respectively; the subscript $j=1,2$ denotes the paths $AB'C'D'$ and $A'D'$, respectively.

For the first orientation, we can find the value of the time $t_{B'C'}$ that takes light to travel the distance between points B' y C' using Pythagoras's theorem with the relation

$$\left(vt_{B'C'}\right)^2 + \left(L_2\right)^2 = \left(ct_{B'C'}\right)^2 \tag{1}$$

We obtain,

$$t_{B'C'} = \frac{L_2}{\sqrt{c^2 - v^2}} = \frac{L_2}{\alpha c} \tag{2}$$

We also have that

$$t_{AB'} + t_{C'D'} = \frac{\alpha L_1}{c - v} + \frac{\alpha L_1}{c + v} = \frac{2\alpha c L_1}{c^2 - v^2} = \frac{2L_1}{\alpha c} \tag{3}$$

From equations (1), (2), (3), and using the fact that $t_{B'C'} = t_{A'D'}$, we have that the time taken by light to travel paths $AB'C'D'$ and $A'D'$ is given by:

$$t_1^1 = \frac{2L_1}{\alpha c} + \frac{L_2}{\alpha c} \tag{4}$$

$$t_2^1 = \frac{L_2}{\alpha c} \tag{5}$$

$$\Delta t_1 = t_1 - t_2 \tag{6}$$

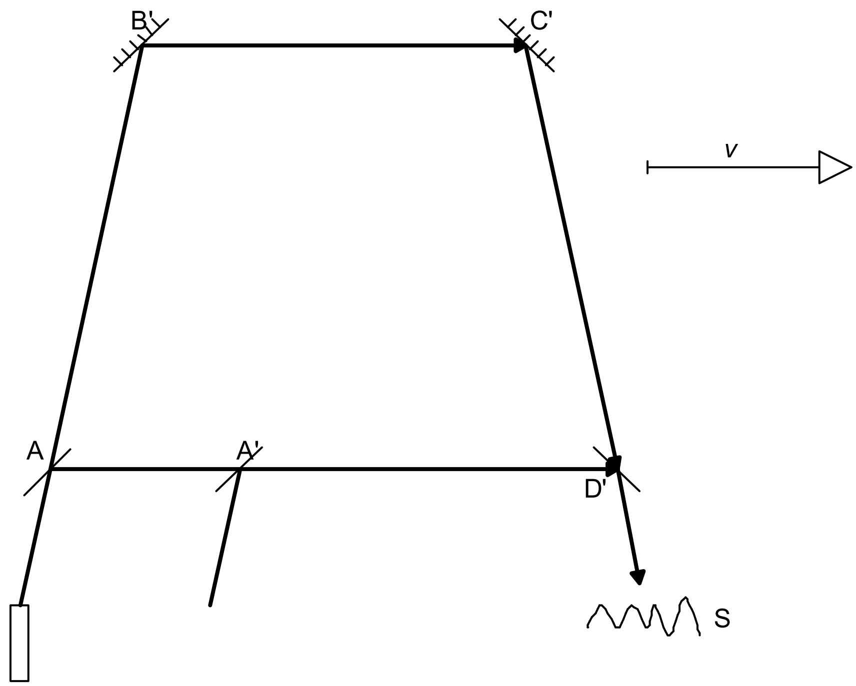

Figure 2 Second orientation of the same interferometer, after a 90º rotation.

Using Figure 2, when the interferometer is rotated 90º (second orientation), we have for the travel times:

$$t_1^2 = \frac{2L_1}{\alpha c} + \frac{\alpha L_2}{c - v} \tag{7}$$

$$t_2^2 = \frac{\alpha L_2}{c - v} \tag{8}$$

$$\Delta t_2 = t_1^2 - t_2^2 \tag{9}$$

From equations (6) and (9), we find that

$$\Delta t = (\Delta t_2 - \Delta t_1) = 0 \quad (10)$$

The result obtained in equation (10) is the expected one, and is a direct consequence of considering Lorentz-Fitzgerald contraction α. This result means that, at D', there is no phase change as a consequence of rotating the interferometer.

However, it is important to notice that, although $\Delta t = 0$,

$$t_1^2 > t_1^1 \quad (11)$$

And that

$$t_2^2 > t_2^1 \quad (12)$$

That is, the time taken by light to travel the distance between points $AB'C'D'$ (or $A'D'$) in the first orientation *is smaller* than the time taken to travel the same paths in the second orientation of the interferometer.

Given that the radius r of a sphere of light can be calculated as $r = ct$ we have from equations (11) and (12) that the distance traveled by light in the first orientation *is smaller* than the distance traveled in the second orientation of the interferometer.

It is important to emphasize that the results obtained in equations (11) and (12) *are not obtained* when using a M&M type interferometer, because light travels each arm of the interferometer in a *two-way fashion*, thus obtaining $t_1^2 = t_1^1$ and $t_2^2 = t_2^1$.

The results of equations (11) and (12) enables us to explain why the interferometer is sensible to anisotropies in the speed of light when the interferometer is rotated: equation (10) says that there is no phase change in the interference pattern that forms in D', however equations (11) and (12) say that the radii of the spheres of light from the source to D' (the observer) is different in each orientation of the interferometer.

The change ΔS in this distance is,

$$\Delta S = c\left(t_2^2 - t_2^1\right) = c\left(t_1^2 - t_1^1\right) = cL_2\left(\frac{\alpha}{c-v} - \frac{1}{\alpha c}\right) \tag{13}$$

For the proposed interferometer, it can be verified that ΔS is identically equal to zero just in the case when $v = 0$. For a M&M interferometer $\Delta S = 0$ for all v, because $t_2^2 = t_2^1$ and $t_1^2 = t_1^1$: the radii of the spheres of light from the source to D' remain constant when the interferometer is rotated.

As it was already said, for both beams to arrive simultaneously at D', we have to consider that one beams traverses A, and the other is reflected at A' when the beam splitter located at A has moved to A'.

We can see that $\overline{AA'} = v\frac{2L_1}{\alpha c}$ has the same value in both orientations. This expression means that the interferometer has moved with velocity v during the time $\frac{2L_1}{\alpha c}$.

For an observer at D', the interference pattern is produced by the interference of two beams: one beam transmitted at A and another one reflected at A', both arriving simultaneously at D'. The difference between the radii of the spheres of light is $r_2^i - r_1^i = \frac{2L_1}{\alpha}$.

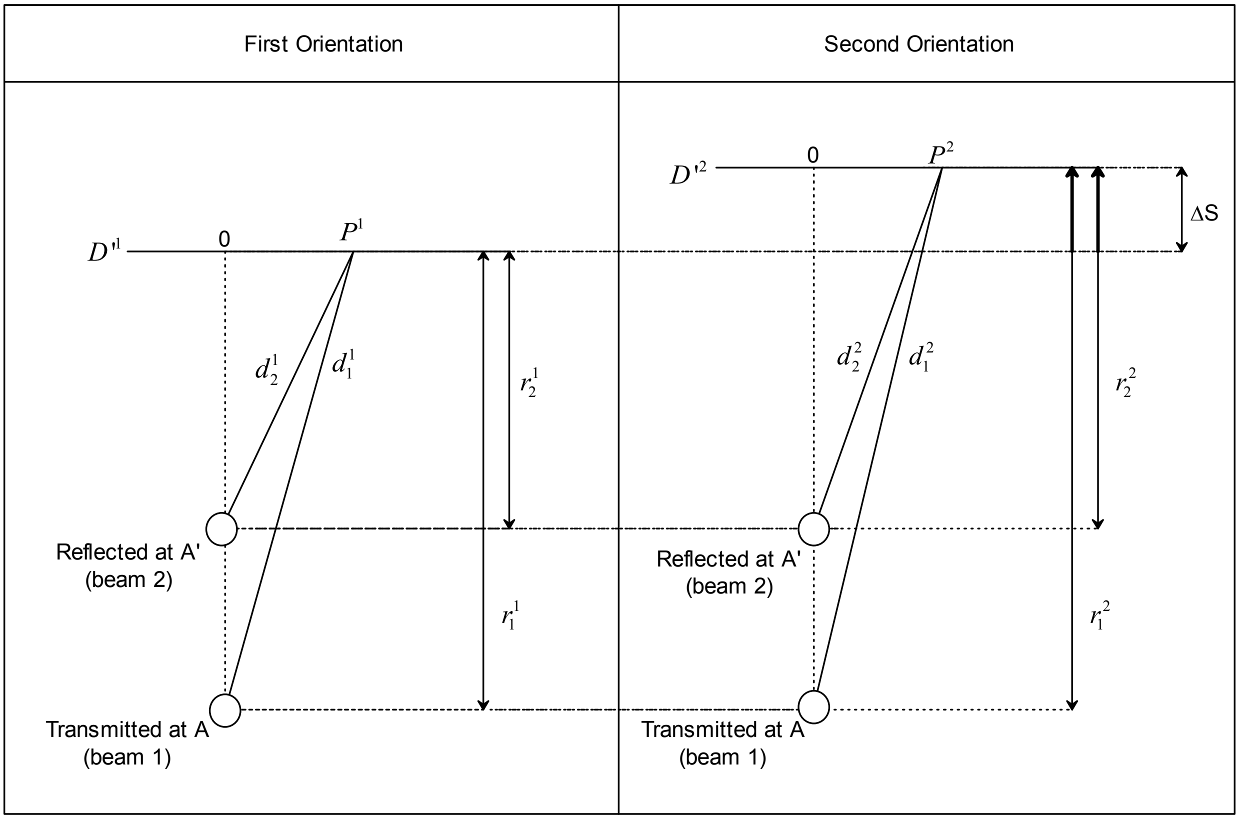

Figure 3 In each orientation, the interference pattern is formed by two beams: one that is transmitted at A, and another that reflects at A', arriving both beams simultaneously at D'. The difference between the radii of the spheres is greater than zero and of constant value in both orientations. In the second orientation, both beams have to travel an additional distance ΔS to arrive to D'.

In reference to Figure 3, P^1 and P^2 represent a fixed distance from the origin 0. They are the position of the observer with respect to the source of light for each orientation. The distances $r_j^i = ct_j^i$ correspond to the perpendicular distances from the source to the beam splitter, for each orientation. The $\overrightarrow{d_j^i}$ represent the distance traveled by light from the source to the observer in each orientation.

It is a known fact the phase Φ^i in a point P^i on D'^i can be calculated as

$$\Phi^i = k\left(\left|\overrightarrow{d_1^i}\right| - \left|\overrightarrow{d_2^i}\right|\right) \tag{14}$$

Where $k = \dfrac{2\pi}{\lambda}$ is the wave number, and λ is the wavelength of the light used.

Because in the second orientation the beams have to travel an additional distance ΔS to reach the observer, it should be clear that $d_j^2 > d_j^1$.

We define

$$\Delta\Phi = \Phi^2 - \Phi^1 \tag{15}$$

As can be verified, in general, $\Delta\Phi \neq 0$. This states the fact that there *is* a phase change *from the point of view of the observer*. This doesn't contradict the result obtained in equation (10), which states that the interference pattern *is the same in both orientations*.

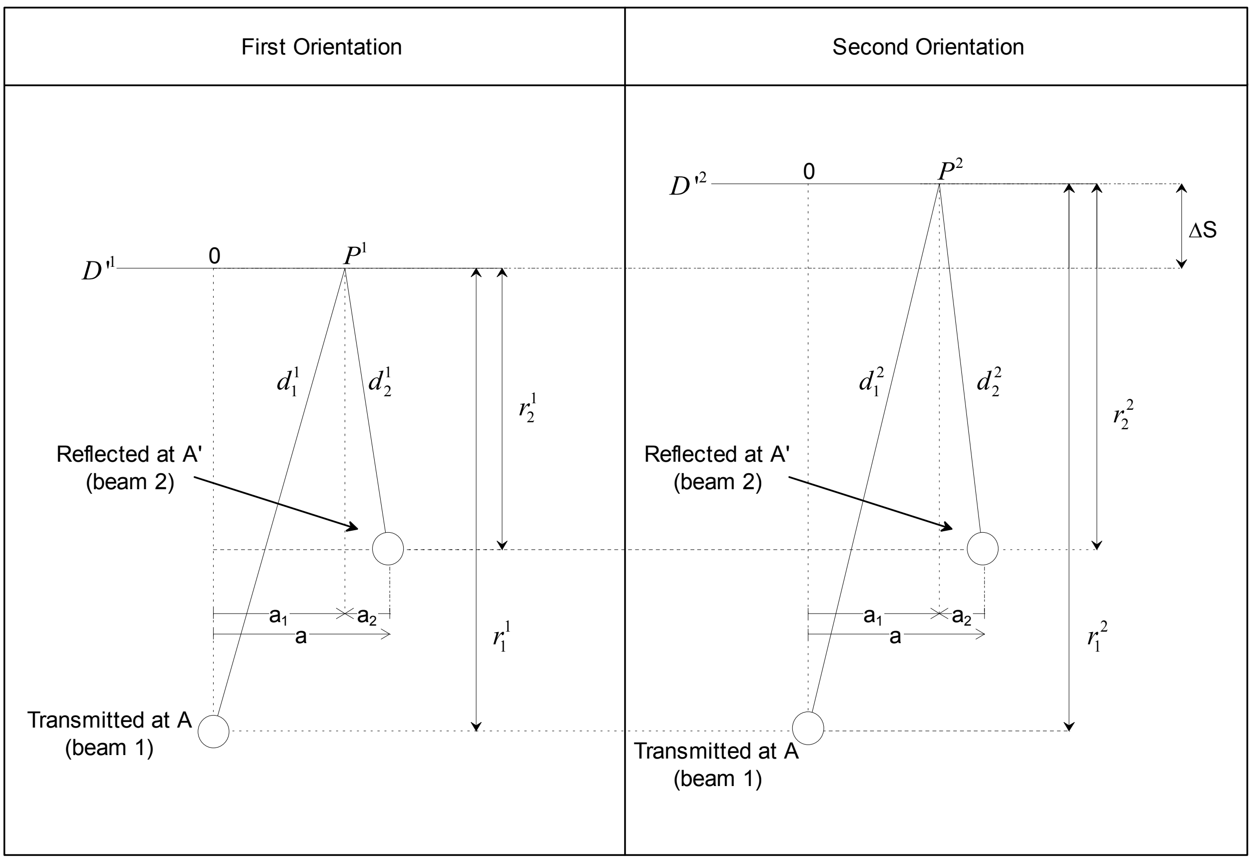

Figure 4 Schematic behavior of the interference pattern formed by the two beams. The points P1 y P2 represent the position of the observer in each orientation. In this figure, we consider also a misalignment, represented by the lateral (vectorial) distance a=a_1-a_2 between the beams.

Figure 1, Figure 2 and Figure 3 represent a perfectly aligned interferometer. In practice, in order to observe interference fringes, the interferometer must be slightly unaligned. That is, the angles of the mirrors and beam splitter don't have exact 45º inclinations. Figure 4 show an interferometer slightly unaligned. This misalignment is represented in the figure with the lateral distance between beams $\overrightarrow{a} = \overrightarrow{a_1} - \overrightarrow{a_2}$. The distances $\left|\overrightarrow{a_j}\right|$ correspond to the modulus of the projection of $\overrightarrow{d_i^i}$ over $\overrightarrow{a}$.

The points P^i correspond to the fixed position of the observer with respect to the origin 0.

The distances $\left|\overrightarrow{d_j^i}\right|$ of the optical paths $\overline{AB'C'D'}$ and $\overline{A'D'}$ are equal to $\left|d_j^i\right| = \sqrt{\left|\overrightarrow{r_j^i}\right|^2 + \left|\overrightarrow{a_j}\right|^2}$, where $\left|\overrightarrow{r_j^i}\right| = ct_j^i$.

The phase change that an observer measures when the interferometer is rotated (and thus passing from P^1 to P^2) is given by

$$\Delta\Phi = k\left(\left|\overrightarrow{d_1^2}\right| - \left|\overrightarrow{d_2^2}\right|\right) - \left(\left|\overrightarrow{d_1^1}\right| - \left|\overrightarrow{d_2^1}\right|\right) \tag{16}$$

Where λ is the wavelength of light. This is equivalent to a number of fringes $N = \dfrac{\Delta\Phi}{2\pi}$.

From equation (16) it can be seen that the more unaligned the interferometer, the greater fringe shift must be measured.

The effect described in this paper can be visualized in the next figure:

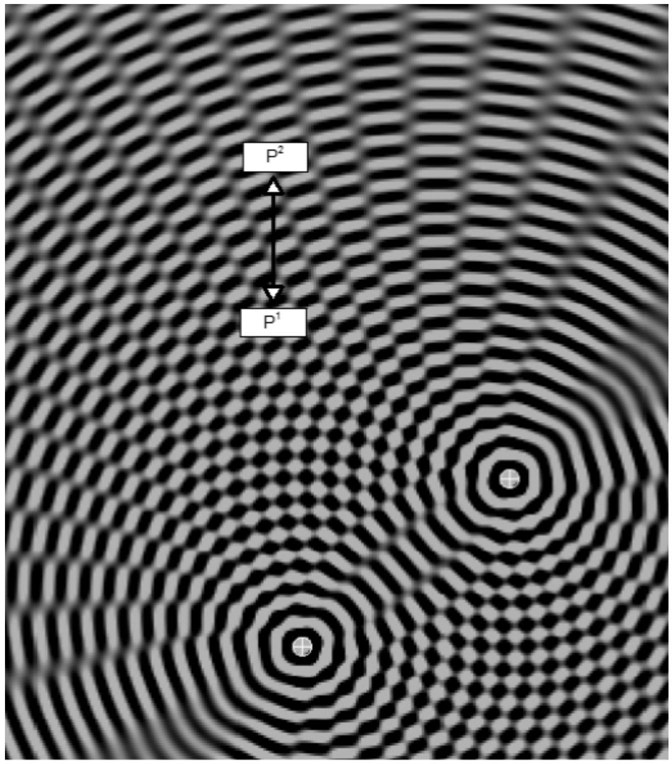

Figure 5 Unaligned interferometric setup. This figure represents a snapshot of the spheres of light propagating away from the source. The two beams that form the interference pattern are one transmitted at A and the other reflected at A'. When the interferometer is rotated the observer measures the pattern at points P^1 and P^2, thus measuring an apparent fringe shift. In this figure, the observer measures N≅1,5.

Figure 5 represents a snapshot of the spheres of light propagating away from the source. The two beams that form the interference pattern are one transmitted at A and the other reflected at A'. When the interferometer is rotated, the observer measures the pattern at points P^1 and P^2, thus measuring an apparent fringe shift.

In the case of an M&M type interferometer, in Figure 5 the distance between P^1 and P^2 is equal to zero.

Additional Results

Because the main objective of this paper is to show theoretically the results that should be obtained when a one-way interferometer is rotated if a preferred frame of reference exists, it escapes the scope of this paper to describe *in detail* the experimental procedure already done by the authors to verify the results. To illustrate the reader, and to encourage further and more precise verifications of our results, it is convenient to show some data plots of the data (*raw*) obtained with an interferometer as the one preciously described.

Instead of rotating the interferometer, it was *left at rest* in the laboratory, while the Earths rotates and orbits around the sun. Experiments have been going on for approximately four months, in different configurations, and the results are consistent among themselves and the theory.

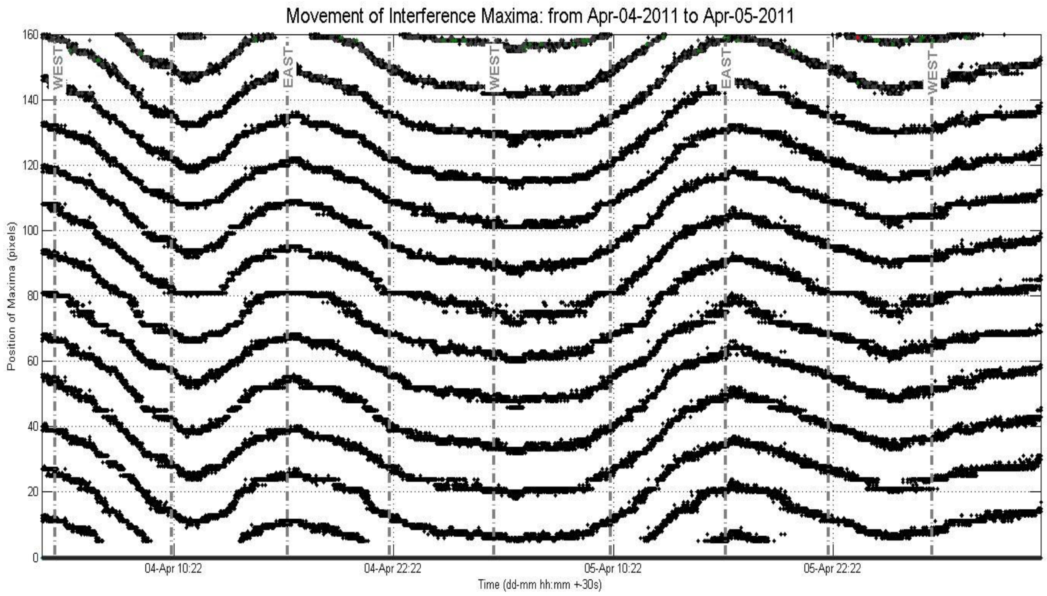

Figure 6 Raw data plot of the experimental results done by the authors as verification to the presented formulation. The horizontal axis is time, the vertical axis is the vertical position on the screen of the interference pattern's maxima. Although the sinusoid are not perfect, it can be seen an apparent correlation between the sinusoid and the position of HIP24255 in the local "East" and "West".

In Figure 6 the horizontal axis represents time (30s precision), while the vertical axis represents the vertical position (measured in pixels) of the interference pattern's maxima. The visible undulations correspond to the movement of the interference maxima from one side to the other on the viewing screen while the earth rotates. The vertical lines tagged with "East" and "West" denote the timestamps when the stellar object HIP54255 appears in the horizon on the earth's sky, as seen from the laboratory (located N 10º32', W 66º55'). Qualitatively, it can be seen an apparent correlation between fringe displacement and the position in the sky of HIP54255. The apparent position of the object in earth's sky of this constellation is approximately equal to the direction of the velocity of the local group of galaxies with respect to CMB's rest frame [2].

Given that the temperature was monitored (0,1K precision) so as the input voltage of the laser (0,1V precision) and no correlation was found with the observed fringe movement, the authors believe that the deviations from the ideal sinusoid are caused by natural laser (He-Ne, 632nm) instabilities, and

because of the tridimensional nature of earths velocity, which also affect the optical paths, and are not studied in the above equations.

Conclusions

It has been described and analyzed an interferometer sensitive to anisotropies of the speed of light. The most important difference of this interferometer with a M&M type interferometer is that light travels the distances between $A'D'$ and $B'C'$ in a *one way fashion*. When the interferometer is rotated (Figure 1 to Figure 2), the radii of spheres of light between source and observer increases, which explains the changes observed in the interference pattern. In a M&M type interferometer, each arm is traveled in a *two way fashion*: the radii of the spheres of light between source and observer are of the same magnitude on all orientations, thus no change in the interference pattern is seen.

In this paper we have considered a rotation of the interferometer from the first to a second orientation (0º to 90º). However, it can be verified that the maximum fringe shift occurs during a rotation from the second orientation to the “fourth” (90º to 270º).

It is important to notice that Lorentz-Fitzgerald contraction was introduced, from the classical perspective, to account for the null result reported by M&M in their famous experiment. However, taking into account this effect (and thus maintaining the null result reported by M&M), and from the classical perspective (the existing of a preferred frame relative to which light’s speed is isotropical and equal to the constant value of ‘c’), it has been shown that using the proposed interferometer it is possible to detect changes in the interference pattern upon rotation, when $v > 0$.

We can also notice that because there is no relative motion between parts of the interferometer, according to the Special Theory of Relativity (STR) no changes in the interference pattern should be expected when the interferometer is rotated. Using classical (pre-relativistic) notions it is shown that although there is no relative motion between parts of the interferometer, motion with respect to a preferred frame can be detected as fringe shifts upon rotation of the interferometer.

It is interesting to mention that the Mach-Zehnder (MZ) interferometers, because of their one-way nature, are *also* sensitive to the detection of anisotropies in the speed of light. In fact, the interferometer described in this paper could be understood as a variation of the MZ type. Yet more interesting is to think a MM as a MZ ‘folded back upon itself’ [3], with the difference that the same beam splitter is used to divide and to recombine the beams of light. This is equivalent to bring together

the beam splitters of a MZ (realigning the mirrors correspondingly). While the beam splitters are brang together, the MZ interferometer transforms gradually into a MM interferometer, also gradually transforming its one-way nature into a two-way. Just before the beam splitters are in the exact same positions, the deformed MZ interferometer looks like a slightly unaligned MM interferometer, with vestiges of sensibility to anisotropies. As has already been told in this paper, the misalignment is proportional to the number of fringes that shift when the interferometer is rotated. It is the opinion of the authors that this is the main reason why experiments using MM type interferometers have not measured identically null results, but always report velocities with magnitudes much smaller than expected (unless, of course, the interferometer is perfectly aligned, in which case an identically null result is expected).

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